MI-144

1990 REPORT ON BRIDGE DECK WATERPROOFING

MATERIALS INFORMATION

MATERIALS OFFICE

91-04072/

1990

REPORT ON

BRIDGE DECK

WATERPROOFING

BY

R.C.EVERS

CONCRETE SECTION
ENGINEERING MATERIALS
OFFICE

JANUARY 1991

ISSN 1183-3866

SUMMARY

In 1990, the Ministry of Transportation monitored the thickness of waterproofing membrane placed on bridges under its authority, as well as the quality of the membrane.

Membrane thickness is controlled by an end result specification (ERS) which was introduced in 1986.- This specification was expanded in 1987 to include membrane quality.

This report contains a summary of the data assembled and comments on the level of compliance with specified tolerances. Comparison is also made to data of previous years.

Problems with contract administration, improper compiling of "Waterproofing Membrane Thickness Report" forms and "Concrete Product Field Sample Sheets" are discussed.

From an analysis of the contained data, it is concluded that membrane thickness compliance is slightly less than over the previous two years and membrane quality has remained at an unsatisfactory level of 19% failures.

New initiatives, in the form of increased price reductions, have been implemented in an effort to mitigate the problem of material failures.

INDEX

INTRODUCTION	1
DATA ANALYSIS	1
DISCUSSION	5
FIELD ADMINISTRATION	7
CONCLUSION	7
RECOMMENDATION	7
APPENDIX (Data Summaries)	8

1 INTRODUCTION

1.1 Acceptance Criteria

Bridge deck waterproofing is accepted under an "end result specification" (ERS). This ERS provides for a price reduction or rejection for work which fails to meet specified requirements for material thickness and quality. The thickness component of this ERS was first implemented in 1986 after a three year interim acceptance system which introduced the principles of ERS. The quality component was added in contracts awarded after September 1987.

1.2 Material Thickness

For 1990, the Concrete Section of the Engineering Materials Office received 343 waterproofing thickness reports from across the Province, representing 121,420.5 m^2 of waterproofing. This is the largest number of lots constructed in any year since the introduction of acceptance by lots in 1983. The data from each report was entered on a micro computer spreadsheet. The micro computer was used to sort, analyze and graphically depict the accumulated data.

1.3 Material Quality

The Concrete Section tested 318 samples of hot applied, rubberized asphalt waterproofing membrane in 1990. Two of these samples were approval samples and 316 were quality assurance samples. This represents an 86% increase over the number of samples tested in 1989. These samples represent products from four manufacturers as submitted from contract job sites. The samples were obtained from the contractor's melting kettle, by the contractor at a time determined by the inspector, so as to be representative of material placed on the bridge deck.

Many of the samples received were substantially less than the four litres required which can preclude re-testing of a failed sample if requested by a contractor. The "Concrete Products Field Sample Sheets" accompanying the samples were frequently missing all the required documentation as enumerated in the "Field Guide For Acceptance Of Hot Mix and Bridge Deck Waterproofing". In fact, five samples received were not tested because of insufficient quantity.

The samples were tested for compliance with six specification requirements:

1. Cone Penetration	@ 25°C	max.	110	(0.1 mm)
2. Cone Penetration	@ 50°C	max.	160	(0.1 mm)
3. Flow	@ 60°C	max.	3	(mm)
4. Low Temperature Flexibility	@ -25°C		Pass	
5. Toughness		min.	5.5	(Joules)
6. Toughness/Peak Load Ratio		min.	0.040	

The test results were entered on a micro computer spread sheet program.

2 DATA ANALYSIS

2.1 Material Thickness

Of the 341 lots reported, 14 were borderline and 1 was rejectable on the basis of the original sampling. (Refer to Provincial Highways report EM-79 for acceptance criteria.) The one rejectable lot, after repair by the contractor, became borderline and received a payment adjustment of 0.99. In another case, a borderline lot was to receive a payment adjustment of 0.64 and the contractor elected to repair the lot and received full payment.

The average thickness and standard deviation of membrane has remained virtually the same over the last four construction seasons. The average thickness is very close to the target of 5 mm and the standard deviation reflects acceptable process control. Table 1 depicts the thickness statistics from 1984 to 1990.

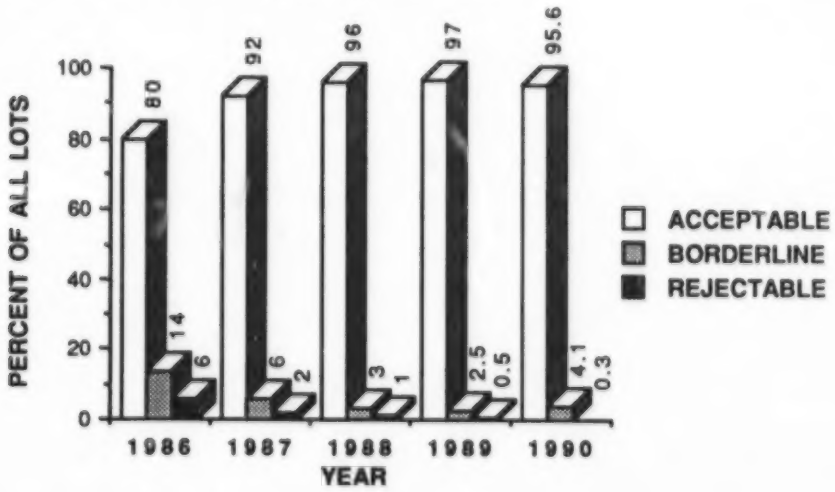
TABLE 1: ANNUAL MEMBRANE THICKNESS SUMMARY

YEAR	NO. OF LOTS	MEAN THICK. (mm)	AVG. LOT ST. DEV.
1984	261	4.7	0.75
1985	306	4.8	-
1986	157	4.9	0.70
1987	254	4.9	0.63
1988	319	4.9	0.63
1989	189	4.9	0.63
1990	341	4.9	0.64

The larger number of lots for 1985 and 1988 are due to the waterproofing of the new and rehabilitated Burlington Bay Skyway bridges respectively, each of which had 75 lots. The increase in 1990 is the result of the expanded five year capital program with construction of many new structures as well as structure rehabilitation projects. It is expected that in 1991 there will be a further increase in the quantity of bridge deck waterproofing.

In 1986, only 80% of all lots constructed were acceptable, improving to 97% in 1989 and falling off to 95.6% in 1990 . Figure 1 depicts the yearly achievement.

FIG. 1: ANNUAL THICKNESS COMPLIANCE



Twelve waterproofing contractors shared the work in 1990. Figure 2 demonstrates how the work was divided between the contractors. Of the twelve contractors, only six had all lots accepted at full price, five had some borderline and one had a rejectable lot. Figure 3 depicts the relative performance of each contractor (identities concealed).

Individual contractors' statistics are presented in the appendix.

FIG. 2: CONTRACTOR'S SHARE OF WORK

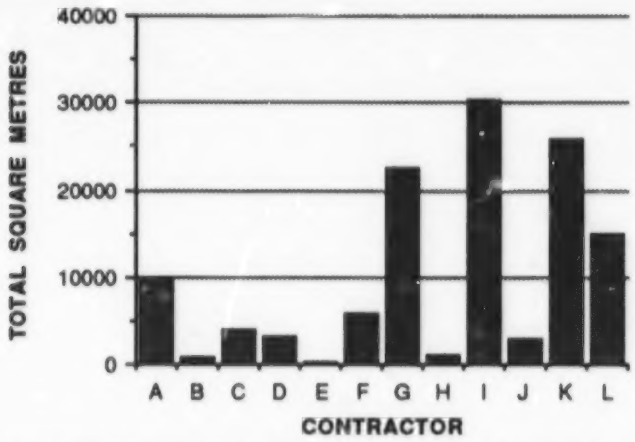


FIG. 3: CONTRACTOR PERFORMANCE (MATERIAL THICKNESS)

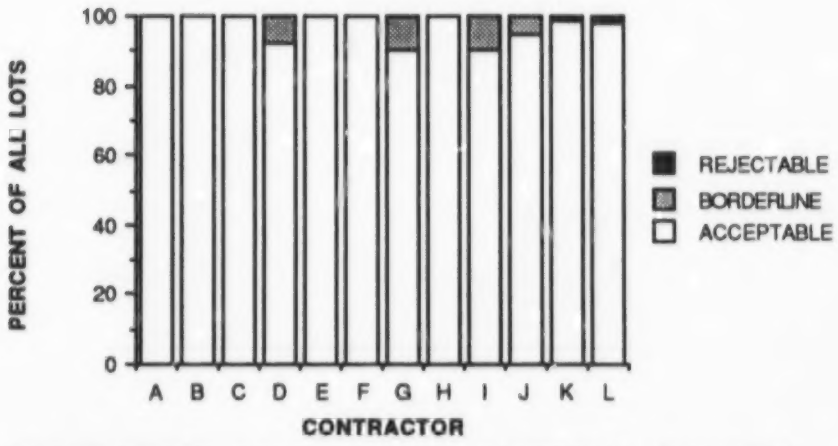


FIG. 4: CONTRACTOR PERFORMANCE (MATERIAL QUALITY)

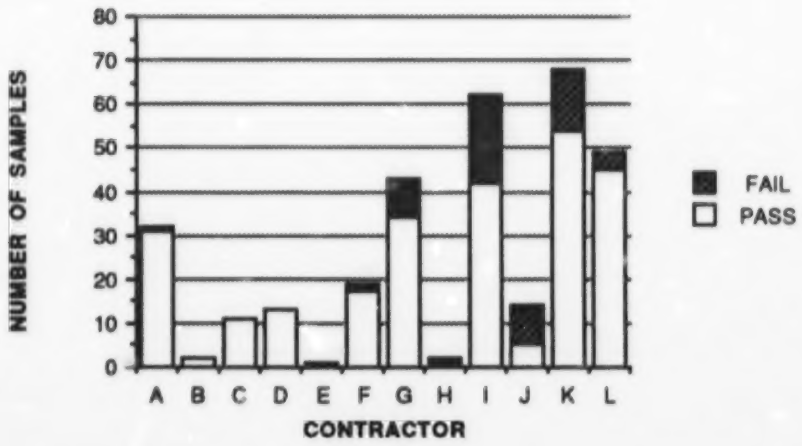


FIG. 5: FOUR YEAR HISTORY OF QUALITY TESTS

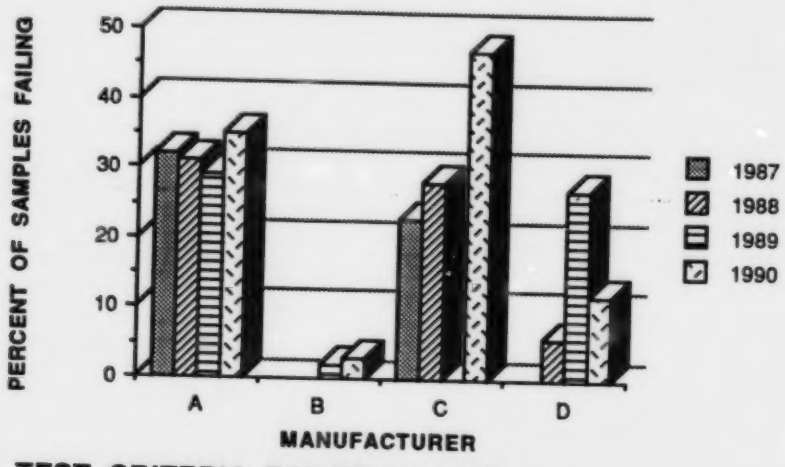


FIG. 6: TEST CRITERIA FAILED IN 1990

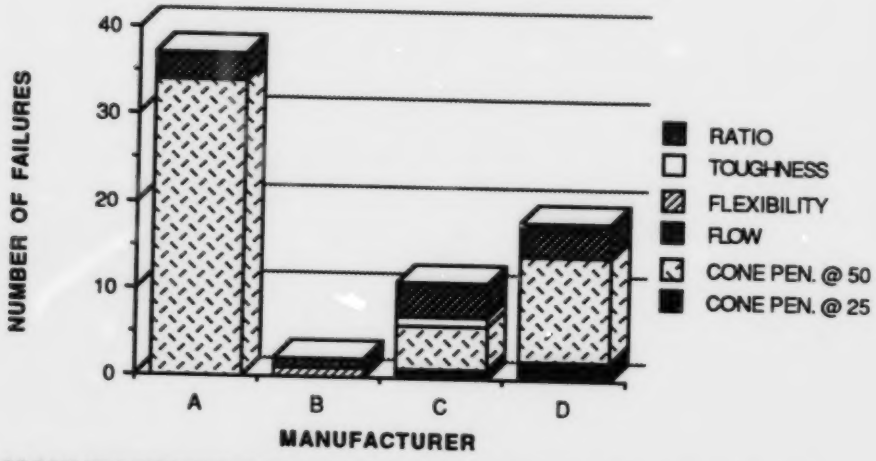
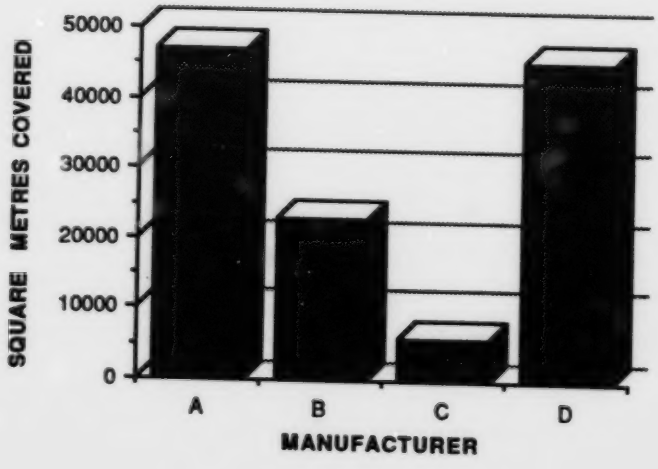


FIG. 7: MANUFACTURER'S SHARE OF AREA PLACED IN 1990



2.2 Material Quality

Three hundred and sixteen quality assurance samples, representing material from four manufacturers, were tested in the Downsview laboratories. Eighty one percent of the samples met all test criteria with 19% failing one or more of the quality tests. Sixty one samples failed, resulting in a price reduction for sixty lots and no payment for one lot of rejectable material. Failures occurred in five of the six quality criteria; only the flow requirement was consistently met. Figure 4 shows how the material failures relate to individual contractors, Figures 5 and 6 demonstrate the proportions of samples failing tests. The Price Adjustment Factors ranged from a low of 0.000 for the rejectable lot to a high of 0.999 with an average of 0.979 excluding the 0.000 from the average. Figure 7 demonstrates the distribution of the four manufacturers products on Ministry work. Individual manufacturers' statistics are contained in the appendix.

2.3 Material Mass Density

Although not a specification requirement, the mass density of each sample is determined in the laboratory. This mass density along with the other tests can be used to ascertain whether the sample is representative of the material as identified on the sample sheet. Since the various products have different mass densities, it is a useful tool to determine if a sample has been adulterated.

From the mass density of each product, the quantity required to cover a given area may be determined. Table 2 presents the quantity of product required to cover a square metre with 5 mm of membrane based on the mean mass density determinations of the four products supplied to the Ministry in 1990.

TABLE 2 : MATERIAL REQUIRED PER SQUARE METRE OF BRIDGE DECK (5 mm thick)

PRODUCT	kg/m^2
BAKELITE 790-11	5.95
BEMAC BEMALASTIC	7.75
HYDROTECH 6120 BD	5.75
PERMAQUIK 6100 BM	6.20

3 DISCUSSION

3.1 Material Thickness

The level of compliance improved each year from 1986 until 1990 when a slight decline occurred. This decline is attributed to contractors "G" and "I", each of who constructed a large proportion of the lots, and were noted to exercise a very low level of process control. Contractor "L", who has typically exercised a high level of process control, had only two lots in the last five years that did not qualify for full payment. The one rejectable lot in 1990 was constructed by this contractor, who was required to waterproof around protuberances in the deck, which it was claimed, lead to excessive variation in material thickness.

The average lot thickness and lot standard deviation has remained static for the last four years. This suggests that these numbers are not likely to change much in the future. Any contractor attempting to reduce the quantity of material used (thinner membrane) will have to exercise a greater level of process control to avert the possibility of a price adjustment due to variability.

3.2 Material Quality

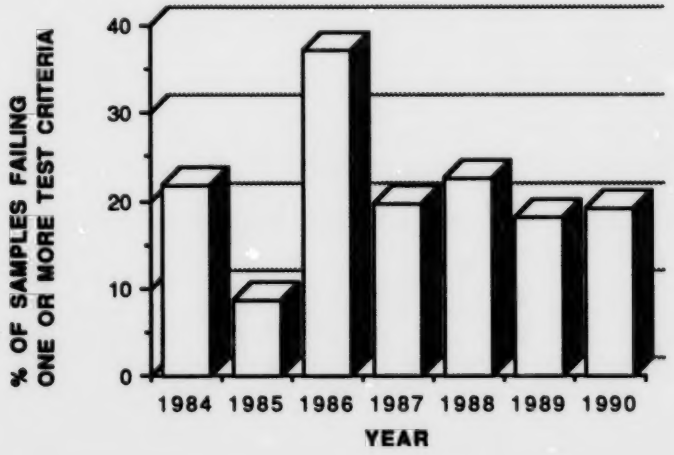
An analysis of the test data over the last seven years shows that, on average, twenty percent of all material samples have failed one or more of the six test criteria. This is demonstrated in Figure 8.

In 1986 the Ministry changed the requirement for cone penetration at 50° C from a maximum of 200 down to a maximum of 160. Although the manufacturers have attempted to meet this new requirement, it has been the most frequently failed criteria in the last three years. Failure of this test can sometimes be attributed to prolonged heating, overheating or reheating, in the contractor's kettle. In 1990, sixteen percent of the samples failed this requirement.

Three of the four manufacturers suppling to Ministry work in 1990 had samples fail the penetration requirement. Two of these manufacturers wrote to their applicators asking them to exercise greater process control over the heating of membrane material. The Ministry, by way of an internal memorandum, requested that inspection staff monitor more closely the temperature of material in the contractor's kettle and to record the product temperature at the time of sampling. A representative of the Concrete Section visited three projects on which the material with the most failures was being used and closely monitored the material temperatures in the contractor's kettles. During the monitoring periods, the material was kept within the manufacturer's recommended range for application. All of the samples taken from the kettles during the monitoring periods passed all test requirements. The above initiatives appear to have had a positive impact, since the frequency of failures dropped toward the end of the construction season.

In order to provide a greater incentive for the industry to comply with the requirements for cone penetration, the Ministry has quadrupled the adjustment points for failure in contracts advertised after January 1, 1991. This means that a sample failing by 10 penetration points will be subject to a price adjustment factor of 0.96 (4% reduction) instead of 0.99 under the previous criteria.

FIG. 8: MANUFACTURER'S SEVEN YEAR HISTORY



4 FIELD ADMINISTRATION

4.1 Material Thickness

Compilation of the Waterproofing Membrane Thickness Reports has improved over previous years but some still are received with missing information and/or incorrect computations.

Following are some of the most common errors:

a. Stages, rather than whole bridge decks, are divided into lots. This results in the same lot number appearing twice for one bridge,

b. The "brand" name of the membrane used is not recorded in the space for "Membrane",

c. The standard deviation is incorrectly rounded off. It should be rounded to the closest 0.05. Incorrect rounding can make a significant difference in the determination of the payment adjustment factor.

4.2 Material Quality

Many samples are received without the Concrete Products Field Sample Sheet being adequately completed. Field staff should refer to the "Field Guide For Acceptance Of Hot Mix and Bridge Deck Waterproofing", to make sure that all required information is provided with the sample. This information is critical to our data base and to assure that price adjustment is applied to the correct lot should a sample fail the quality tests.

Approximately 80% of the samples received at the laboratory were less than the required 4 litres. Five could not be tested at all due to insufficient quantity.

Three hundred and twenty one acceptance samples were received whereas 341 lots were reported constructed. This suggests that 20 samples were either not taken, submitted for testing or were somehow lost.

5 CONCLUSION

The introduction of end result specifications for the acceptance of bridge deck waterproofing has had the desired impact of improving compliance to thickness requirements.

The quality component of the end result specification has had little impact on improving compliance to material requirements. The quadrupling of the adjustment points for failing the cone penetration requirements is intended to mitigate this situation.

Field testing in 1990 indicates 95.6% of all lots met thickness requirements on the first assessment.

Laboratory testing shows 81% of all samples tested complied for quality.

There are continuing problems with contract administration and documentation.

6 RECOMMENDATION

Quality Assurance staff should review the acceptance procedures for bridge deck waterproofing with the Project Supervisor, with particular emphasis on computations and documentation prior to commencement of all waterproofing work.

CONTRACTOR	AVE. THICK.	AVE. ST. DEV.	SQ. METRES	TOTAL NUMBER OF LOTS	NUMBER OF BORDERLINE LOTS	NUMBER OF REJECTABLE LOTS	NUMBER OF MATERIAL SAMPLES	NUMBER OF MATERIAL FAILURES
E	4.60	0.70	153.0	1	0	0	1	0
B	5.40	0.98	690.0	2	0	0	2	0
H	5.20	0.52	1,014.6	2	0	0	2	2
J	5.23	0.66	2,928.8	20	1	0	14	9
D	4.99	0.54	3,267.4	12	1	0	13	0
C	5.14	0.65	4,009.5	11	0	0	11	0
F	5.09	0.72	5,663.0	24	0	0	19	2
A	5.00	0.65	10,062.9	31	0	0	32	1
L	4.88	0.55	14,883.5	57	0	1	49	4
G	4.59	0.57	22,449.5	52	5	0	43	9
K	4.97	0.71	25,930.5	67	1	0	68	14
I	4.83	0.68	30,367.8	62	6	0	62	20
		TOTAL	121,420.5	341	14	1	316	61

MANUFACTURER	AVE. THICK.	SQ. METRES	NUMBER OF SAMPLES TESTED	NUMBER OF SAMPLES FAILED	FAILED CONE PEN. @ 25 C	FAILED CONE PEN. @ 50 C	FAILED FLOW	FAILED FLEXIBILITY	FAILED TOUGHNESS	FAILED RATIO
C	4.94	6,022.4	19	9	1	5	0	0	1	4
B	4.94	22,864.7	65	2	0	0	0	1	0	1
D	4.94	45,529.3	137	16	2	12	0	0	0	4
A	4.82	47,004.3	97	34	0	34	0	0	0	3
	TOTAL	121,420.7	318	61	3	51	0	1	1	12